Journal of Air Transport Management 40 (2014) 65–77

Contents lists available at ScienceDirect

Journal of Air Transport Management

journal homepage: www.elsevier.com/locate/jairtraman

A green approach to the weight reduction of aircraft cabins

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ARTICLE INFO

Article history:
Available online 1 July 2014

Keywords:
Corporate Social Responsibility (CSR)
Activity-Based Costing (ABC)
Theory of Constraints (TOC)
Mathematical programming model

ABSTRACT

In response to the growing problems of climate change and global warming, airline companies, as members of the global village, are actively promoting energy-saving and carbon reducing measures, and are strictly controlling and managing greenhouse gases generated in the process of providing high-quality transportation services in an attempt to reduce environmental impacts. As environmental protection has become an indicator of Corporate Social Responsibility (CSR), this study integrates Activity-Based Costing (ABC) and the Theory of Constraints (TOC) and adopts a mathematical programming model in an attempt to provide the airline industry with a method to lower fuel consumption by reducing the weight of seats in passenger cabins. In order to contribute to environmental protection, future research could develop a variety of energy-saving and carbon reducing programs on the basis of this model.

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1. Introduction

Over the past two centuries, the concentration of carbon dioxide in the atmosphere has increased by 25–35% and, as the sun's heat gathers in the troposphere, has caused global warming and climate change (Kugele et al., 2005). In response to this, governments have promoted a series of carbon reducing strategies (Mayor and Tol, 2008; Upham, 2001; Upham et al., 2004) and have come to regard the possible impact of reducing emissions on economic development as an important contemporary issue (Tonn, 2003). Heat radiation caused by the greenhouse gases released by the aviation industry accounts for about 3% of mankind's total CO_2 emissions (Butterworth-Hayes, 2012). As the aviation sector is not included in the Kyoto Protocol or the supplementary specifications of the United Nations Framework Convention on Climate Change (UNFCCC) and given the amount of emissions from this sector, its impact on the atmosphere cannot be underestimated (Schumann, 2000).

Global warming occurs when temperatures rise between 1.8 and 3.6 °C above pre-industrial surface air temperatures (Hill et al., 2014). As environmental protection has become an indicator of Corporate Social Responsibility (CSR) (Tsai et al., 2012c), which is based on the idea that commercial operations must conform to sustainable development, in addition to considering their own financial and operating conditions, an enterprise should consider its social and natural environmental impact. As numerous industries have become concerned with environmental issues (Tsai et al., 2013b), both the EU and US have planned a variety of energy-saving and carbon reducing programs for the aviation industry in order to save on costs and improve both operational efficiency and profitability (Lyon and Francis, 2006; Mayor and Tol, 2008; Tsai et al., 2012a).

Greenhouse gas emissions are primarily the result of the fossil fuel energy conversion process; with economic growth, people tend to demand increasing amounts of energy and this dependence on fossil fuels will not end in the near future (Ming et al., 2014). Determining how to cope with the possible impact of emission reductions on economic development is an important issue facing countries in the world today (Tonn, 2003).

Therefore the aim of this paper is to provide a carbon emissions reducing method for the airline industry, and whilst it is intended for generic use, it is explained here through its application to a case study. There are some assumptions made in the method that are country-specific. We used examples of airlines in three aviation markets (EU domestic routes, British routes within the EU and North Atlantic routes) in order to illustrate the impact of reducing carbon emissions, and airplane model adjustments, passenger load factor and seat adjustments on the environment (Miyoshi and Mason, 2009). From a different perspective, taking international airports in the UK as an example, reducing the price of tickets increases the number of visitors from the US to Europe, which means that greenhouse gas emissions increase (Mayor and Tol, 2007). In relation to aircraft environmental pollution, Switzerland began to impose air pollution charges in 1997,

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http://dx.doi.org/10.1016/j.jairtraman.2014.06.004
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followed by Swedish airports in 1998 and major airports in the UK in 2004 (Scheelhaase, 2010). In Asia, Taiwan included airports into the air pollution control range in 2002. In fact Taiwan's Air Pollution Control Act expressly provides air pollution reduction incentives.

2. Airlines' carbon reduction measures

Airline companies try to reduce airline fuel cost as much as possible (Naumann and Suhl, 2013), which means that energy conservation becomes an important consideration in terms of aircraft design (Butterworth-Hayes, 2011). Since cruise speed changes optimal flight height, an aircraft can reduce its fuel consumption in only a limited way (Delgado and Prats, 2012). The ground-to-satellite Air Traffic Management (ATM) system is expected to reduce departure delays, as well as control fuel costs and carbon emissions, both of which are of vital importance to airline companies (Warwick, 2011). A fully optimized interactive ATM system is able to reduce an aircraft's fuel consumption by up to 10% (Butterworth-Hayes, 2011). Combined transport has been recognized as a prioritized means of transportation by the European Union (Berrittella, 2010). The carbon emissions of aircraft can be reduced through land-air combined transport, as advanced computer and communication technologies are applied in order to more efficiently determine air routes and flight times (Zito et al., 2011).

Due to intense competition in terms of providing passengers with more comfortable services (Giaconia et al., 2013), and in response to the trend of environmental protection, if a new aircraft cannot be delivered in a short period of time, airline companies may engage in modification activities relating to annual aircraft maintenance that replace cabin interiors with lighter materials as a way to reduce the aircraft's load and so decrease fuel consumption and reduce carbon emissions. In response to CSR, this study integrates Activity-Based Costing (ABC is a cost-accounting system whose institutional core focuses on cost attribution in order to explore the relationships between allocation of resources, amount of work and final product (cost objects)) and the Theory of Constraints (TOC suggests that a complex system may be composed of a series of devices and tens of thousands of people, but that only a few variables, or perhaps only one, will limit (or prevent) this system from achieving higher goals). Moreover, the study adopts a mathematical programming model in order to provide a model for weight reduction using passenger seats as a case study.

2.1. Corporate Social Responsibility (CSR)

Representing the social obligations of the enterprise (Smith, 2003; Tsai and Hsu, 2008), CSR not only accrues benefits but also strengthens public perceptions of an enterprise (He and Lai, 2014; Park et al., 2014). Therefore, a socially responsible enterprise, in addition to creating maximum profits for stockholders, should also be concerned with problems arising in the process of enterprise business conduct and should take on the responsibility of corporate commitments. CSR activities have come to be regarded as an important and indispensable part of corporate activities (Dhanesh, 2014). Through investment in CSR activities, the company and the community are able to achieve maximum benefits (Dougherty and Olsen, 2014; Mackenzie and Peters, 2014).

2.2. Activity-Based Costing (ABC) and the Theory of Constraints (TOC)

Successful cost management should include the management of "activity" rather than merely the management of "cost" as under the traditional cost system (Li et al., 2012). ABC is a cost pricing system that divides the production or service process into a series of basic activities and allocates the costs of various activities to either products or services (Raab et al., 2009; Tsai and Hung, 2009). ABC allocates the resource costs to cost objects in two stages (Tsai, 2010; Tsai et al., 2012a). In the first stage, resource dynamics allocate resources to an activity cost pool that is divided into the unit, batch, product and facility levels according to the level of activity. In the second stage, activity dynamics allocate resources from the activity cost pool to cost objects; these are activities that result in production costs (Wang and Huang, 2013).

Activity-Based Costing (ABC) is a methodology used to measure the operation and performance of operations, resources and cost targets, where the operation is attributed to the resource. The attribution is based on the cost drivers with a causal relationship (Dessureault and Benito, 2012). According to ABC, the enterprise may develop an activity-based economic map of expenses and revenues in order to illustrate the economic design of the organization's expenses and profits (Yamebe et al., 2010). Therefore, ABC can help decision-makers to make the most efficient configuration of resources and thereby facilitate smooth operations. In order to achieve the efficient weight reduction of cabin seats, this study applies ABC in an examination of how to replace weightier cabin seats with new lighter seats, and considers the relevant costs involved so as to achieve the purpose of an efficient replacement of cabin seats and a reduction in aircraft weight.

Every enterprise is a limited resource system and these limitations affect the achievement of goals (Tsai and Chou, 2009). Moreover, the performance of any production system is determined by its weakest process (Ewers et al., 2009). Given this, managers should focus on capacity constrained resources (CCRs) and remove any bottlenecks processes (Glock and Jaber, 2013). ABC provides a systematic approach to analyze non-value-adding activities, procedures and products, and ignores resource limitations (Geri and Geri, 2011). Therefore, TOC may provide better solutions to assist in product portfolio decision-making (Kaijun and Yuxia, 2010).

ABC focuses on the relationship between cost and production from a long term perspective, while TOC focuses on this relationship from a short-term perspective (Tsai et al., 2013a). However, in solving problems relating to short-term operations and long term cost management, ABC and TOC are mutually complementary (Lockhart and Taylor, 2007) and coupled with a Linear Programming (LP) model provide solutions to product portfolio decision-making problems (Tsai and Lin, 1990; Tsai et al., 2011, 2012b).

2.3. A green approach to the weight reduction of aircraft cabin seats

The proposed "Cabin Change Plan" to alter aircraft cabin seats focuses primarily on passenger comfort in the *Boeing*747. In order to cater for the different needs of travelers, the cabin of a large passenger aircraft is divided into the first class cabin, the business class cabin and the economy class cabin according to the amount of space occupied by each seat. After determining the size of the cabin seat, we are able to review the entertainment facilities installed in each seat. The total weight of the small-sized display screen should include the weight of required wiring. As far as the passenger cabin is concerned, if the weight of these two devices can be reduced, this will improve the energy efficiency of the aircraft.

Moreover, the International Civil Aviation Organization ICAO requires that all passengers should be able to evacuate their seats within one minute. However, if the seat pitch is too small, then it may not be able to meet this requirement. Moreover, from the point of view of comfort, seat configuration in narrow spacing can make long-distance passengers very uncomfortable. Therefore, this study takes passenger comfort into consideration and includes spacing adjustments to seat pitch.

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